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Visualization Empowerment: How to Teach and Learn Data Visualization

Citation for published version:

Bach, B, Huron, S, Hinrichs, U & Carpendale, S 2022, *Visualization Empowerment: How to Teach and Learn Data Visualization*..

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

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PART A: Meta Data

Visualization Empowerment: How to Teach and Learn Data Visualization

Abstract

Authors: Benjamin Bach, Samuel Huron, Uta Hinrichs, Sheelagh Carpendale

The concept of visualisation literacy encompasses the ability to read, write, and create visualizations of data using digital or physical representations and is becoming an important asset for a data-literate, informed, and critical society. While many useful textbooks, blogs, and courses exist about data visualization—created by both academics and practitioners—little is known about 1) how learning processes in the context of visualization unfold and 2) what are the best practices to engage and to teach the theory and practice of data visualization to diverse audiences, ranging from children to adults, from novices to advances, from students to professionals, and including different domain backgrounds. Hence, the aim of this Dagstuhl Seminar is to collect, discuss, and systematize knowledge around the education and teaching of data visualization to empower people making effective and unbiased use of this powerful medium. To that end, we aim to:

- **Provide a cohesive overview** of the state-of-the-art in visualization literacy (materials, skills, evaluation, etc.) and compile a comprehensive *handbook* for academics, teachers, and practitioners;
- **Collect and systematize *learning activities*** to inform teaching visualization across a wide range of education scenarios in the form of a *teaching activities cook-book*.
- **Discuss open challenges** and outline future research agendas to improve visualization literacy and education.

Besides those outcomes, we aim to facilitate interdisciplinary research collaborations among attendees; researchers, practitioners, and educators from a wide range of background including data visualization, education, and data science.

Organizers

All organizers are award-winning core members of the international visualization research community and have extensive experience in university, art and design college teaching and are actively conducting research into how to facilitate learning and teaching in data visualization.

- **Benjamin Bach**
Assistant Professor in Design Informatics and Visualization
School of Informatics, University of Edinburgh, United Kingdom
<http://benjbach.me>
Keywords: *professional development, online learning, visual cheat sheets, comics for explanation and visual storytelling, human-computer interaction, controlled and quantitative evaluation*
- **Samuel Huron**
Associate Professor in Design of information communication technologies
Telecom Paris, Institut Polytechnique de Paris, France
<https://www.telecom-paris.fr/samuel-huron?l=en>
Keywords: *constructivism, design research, information design, data physicalization, data workshops, design methodologies, data visualization for empowerment, representation as thinking tool, future literacy*
- **Uta Hinrichs**
Assistant Professor in Human-Computer Interaction and Visualization
University of St Andrews, United Kingdom
<https://sachi.cs.st-andrews.ac.uk/people/faculty/uta-hinrichs>
Keywords: *visualization processes, visualization for children, digital humanities, data physicalization, impact of tools on visualization thinking and process, qualitative in-situ studies*

- **Sheelagh Carpendale**

Professor Computing Science, Information Visualization, Human-Computer Interaction
Simon Fraser University, Canada

<https://www.cs.sfu.ca/~sheelagh> <https://www.sfu.ca/computing/people/faculty/sheelaghcarpendale.html>

Keywords: *teaching and learning in Art and Design, Sketching as a teaching tool, teaching activities for Interaction Design, teaching activities for creating technology that changes across time, leveraging science to inspire design, teaching qualitative evaluation, data visualization for empowerment*

Event Information

- **Type:** Dagstuhl Seminar
- **Duration:** 5 days
- **Size:** 40-45 participants
- **Topics:** Society / HCI Computer Graphics / Computer Vision
- **Keywords:** Information Visualization, Learning, Visualization Literacy, Data Literacy, Data Science, Education/
- **Dates to avoid:**
 - - IEEE VIS (late October)
 - - ACM CHI (late April / early May)
 - - IEEE/CGF EuroVis (early June)
 - - IEEE PacificVis (late April)

PART B: Proposal Text

1 Topic

Within the general foundations of education (reading, writing, maths, arts, etc.), there is little that prepares people to create and engage with data visualizations. Yet, data visualizations, e.g., in the form of infographics or (interactive) charts embedded in online news articles, shared on twitter and other news outlets, or interactive software tools are becoming an essential part of our daily social and professional life. For example, an ever increasing amount of software tools and programming environments to aid the design, creation, and dissemination of visualizations (for a collection see, e.g., <http://vistools.net>) shows that visualization is becoming mainstream and used by an increasing number of people. Given the power of visualization to communicate, demonstrate—and in the worst case *manipulate*—we must ensure not only a responsible use and application of visualization as a communication method but also skills to critically read and interpret visualizations. This can only be achieved by educating people in the creation, use (as well as misuse), and critical interpretation of data visualization.

Discussing methods for teaching and education is crucial, not only to new university faculty and visualization instructors, but also to practitioners in visualization and public engagement, school teachers, etc.—especially since only few of these educators were able to enjoy explicit training in pedagogy and how to educate. At the same time, being part of the global scientific community at the forefront of knowledge generation in data visualization, human-computer interaction, and data science, it is our mission to lead the path in transferring knowledge in effective and creative ways. It is therefore timely to inform the creation of effective means for teaching data visualization and we see a broad range of research initiatives targeting a better understanding of visualization literacy as well as how to educate and teach visualization literacy to large and diverse audiences.

Visualization Literacy

Visualization Literacy [6] has been described as the ability to read, write, and create visualizations of data using digital or physical representations. Visualization literacy involves a wide variety of theoretical knowledge and practical skills related to *visual perception* and *design thinking*, designing and creating visualizations using a range of common *visualization tools*, knowing how to *interpret visualization techniques*, how to *critically identify flaws* and *detect deceptive cases* of data visualizations [22], as well as using visualizations for *effective communication* [24]. Besides being an essential skill for understanding visualizations in the public domain, visualization literacy is essential in the professional world (business and academic) where interdisciplinary collaborations between data scientists, domain experts, developers, designers, and communicators are common. In addition, visualization literacy plays an important role in public engagement activities, private consulting, pre- and high school teaching [4, 1], as well as upskilling for professional development and personal visual analytics [26]. While the list of skills potentially related to facilitating visualization literacy is long, no dedicated frameworks, definitions, and/or practical education pathways exist.

Across domains and disciplines we can consider two core perspectives that require investigation: learning **for** data visualization and learning **through** data visualization(s).

- *Learning **for** visualization* concerns the *acquisition of practical skills* of reading and creating data visualizations as part of any form of application or scenario: presentation, exploration, analysis, etc. This perspective implies questions about effective methods to learn about visualization; about teaching materials; about peoples' needs; tool support etc.
- *Learning **through** visualization* considers *visualization as a process and medium* to help people engage with data, facts, ideas, and knowledge in ways that enables new insights and/or perspectives on the topics at hand. Here visualization is used as a method to learn about other domains.

Our seminar will focus on both: education and learning around visualization in general, as well as teaching methods.

Education Resources

There is no shortage of resources to learn about data visualization from both academic and non-academic authors as well as across domains and disciplines: political sciences, business analysis, social sciences,

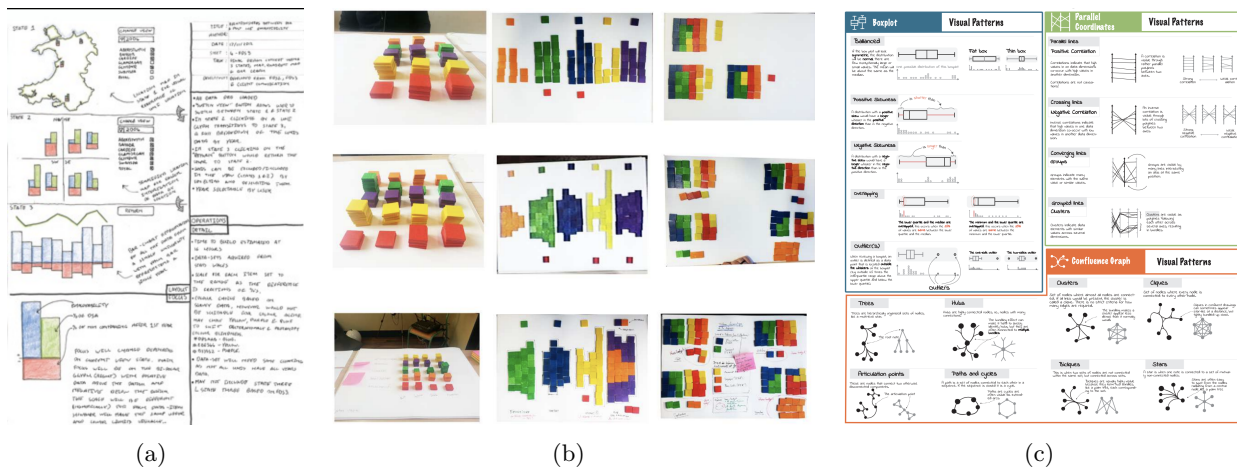


Figure 1: *Examples of learning activities and materials: (a) Five-design sheet methodology [25]; (b) Visualization made out of tokens by non-experts during a visual mapping activity [15]; (c) Cheat Sheets for Data Visualization Techniques [29].*

experimental sciences, humanities, journalism, computer sciences, etc. Example resources include text books (e.g., [7, 19, 17]), technical survey papers, workshops (e.g., [25, 30]), university courses, online courses,¹ blogs,² ³ online catalogues of tutorials for visualization techniques [23], and tools.⁴ ⁵ Besides these easy-accessible and condensed resources meant for consumption by a general audience, academic research in information visualization has yielded a range of empirical results into the perception and the effectiveness of visualization techniques, sometimes formulated and disseminated as guidelines (e.g., [22]). Research on topics of visualization literacy in particular, has been concerned with creating frameworks for assessing visualization literacy [6], skills and theories [5], physical visualizations [15], and the study of visualization activities for young children [4, 8]. These examples show a rigorous and broad approach to define and improve our understanding of visualization literacy, but *little is known about how to engage students and other audience in learning for, and through visualization, what are the skills we need to teach, and how to best teach, communicate, and assess success.*

Education and pedagogy, on the other side, provide numerous frameworks and methods about learning and practical teaching [31, 18]. Besides the traditional learning setup of the individual learner (student) and classroom teaching, learning today also happens in online classes, through forums, tutorials, and peer-learning, often scaling to thousands of students of diverse backgrounds (interdisciplinary, professionalism, etc.). *There is a lack of materials, activities, and frameworks, specific to teaching and learning visualization that helps informing class activities, courses, digital tools, and that take into account the specific affordances of non-traditional learning styles such as online and peer-learning.*

Visualization Activities

This Dagstuhl seminar aims to address these gaps and corresponding questions based on the concept of *data visualization activities*. We define a data visualization activity as any activity that engages an audience in learning about visualization [13]. Part of this Dagstuhl seminar will focus on compiling, brainstorming, and exchanging visualization activities, some of which have been tried and tested by visualization researchers, educators and practitioners. Examples of existing activities include the five-design sheet method for learning visualization design [25], workshops for data comics [28], design spaces and patterns, involving physical tokens [15], creating simple visualization sketches of two quantities [21], self reflection on personal data [26], engaging people with physicalization [14], engaging community in citizen science project [9, 32], and activities to improve data literacy [3, 12]. Data vis activities can involve analogue tools such as pen and paper [27], everyday physical materials [14], or digital visualization tools—both general and/or targeted toward certain learning outcomes [1, 4]. The duration

¹<https://datavis-online.github.io>

²<https://flowingdata.com>

³<https://medium.com/nightingale>

⁴https://vega.github.io/vega-lite/tutorials/getting_started.html

⁵<https://vistools.net>

of activities can also vary from a few minutes to several weeks. Activities have been actively explored for teaching visual mapping concepts, learn a particular visualization toolkit [10], to structure the visualization design process [25], for exploring data collectively [11], generating physicalizations [26, 14], and eliciting phenomenon [20], and for better understanding people's relation to data [11] and empowering citizens [20].

Besides activities, teaching and learning involves a set of bespoke materials that present content or help students train. This can include data sets, example code, templates, design patterns [2], tools, or even "cheat sheets" [29]. However, *we currently lack any idea what material is necessary (to support specific activities), how to design, access, and structure material, in particular material that supports self-driven and individually paced learning, such as used in online courses, tutorials, as well as accompanying visualization tools.*

2 Research Questions

This Dagstuhl seminar aims to bridge the gap between visualization, visualization literacy research, and visualization practice on the one side and education and pedagogy on the other side. Our main goal is to understand the current state of the art in visualization literacy and education and to inform a global research agenda. To that end, this seminar aims to inform both *i)* a **handbook** on visualization literacy as well as *ii)* a **cook-book** on data visualization activities.

This seminar aims to discuss research questions which we group into four categories reflecting the nature of teaching and education: *content, process, context, and assessment.*

Content

By content, we refer to the content of any teaching and education. This mainly includes learning goals, concepts, skills, practical and theoretical knowledge. *Which resources, materials, and best practices exist today to teach visualization?*

- Which are the **skills and competencies** required, such as visual mapping understanding, visual vocabularies, notion of layout, critique, design, programming, etc, to be literate in visualization?
- Which **resources, materials, and best practices** exist today to teach and learn about visualization?
- Which **topics, theories and skills** are being taught in courses, books, and online material today about visualization? E.g., visual mappings, perception, interaction, visualization techniques, fallacies and deception.
- **Which skills are important** for which audiences of students (industry, designers, data scientists, journalists, school children, scientists, etc)

Context

The context refers to any factors that define and inform the content and process of teaching and learning: audiences, their background and learning objectives, scenarios such as online learning, university, school, self taught, online learning, workshop in industry, in science fair or other venue. Each leaning context has implication on the the content and process of teaching and learning. In this group of questions we want to investigate:

- How can we describe different **audiences** for visualization (children, designers, journalists, etc.)
- What do we know about these audiences' **tasks and learning objectives**?
- **What do these audiences know** about visualization and which issues do they struggle with?
- **In which contexts do people engage** and wanting to learn about visualization?
- **In which contexts can people be taught** about visualization?

Process

By process, we refer to the process of teaching, learning, and practicing skills and generally want to ask the question how we teach, learn, and support learners in individual self-paced learning, peer-learning as well guided by active teaching. The process also includes dedicated teaching material in the form of, e.g., textbooks, reading lists, cheat sheets, interactive experiences, data sets, visualization tools.

- **How can we translate knowledge about teaching** from what we know of data visualization learning?
- **How to structure learning process** and learning stages?
- How can we leverage our knowledge of data visualization learning to improve visualization design?
- **How can specific skills be developed**, supported and taught? Examples include theory (e.g., guidelines, concepts, models) and practice (e.g., sketching, programming, evaluation).
- **Which evidence exists** from pedagogy, education, and psychology and which of these are most crucial for designing learning experiences?
- **Which general approaches and styles to teaching work for which contents?** Practice, repetition, discussion, crits, etc.
- How does teaching and learning visualization need to adapt to **specific contexts** it happens in? Examples include online learning, class rooms, self-paced learning.
- How to develop, share, and iterate activities and material in a structured way?
- Which role do **interactive experience** play in supporting learning?
- Which **materials** are required for teaching and how experience be shared? Examples include textbooks, reading lists, cheat sheets, interactive experiences, data sets, visualization tools.
- **How can new teaching material be designed** in a structured way?

Assessment

This group captures questions related to any assessment of the education materials and processes as well as the assessment of students, learning objectives, and progress.

- **How to evaluate educational material** and processes?
- **How to evaluate learning progress** and learning objectives in students?
- **How to assess visualization literacy** on a more general level?

3 Aims and Outcomes

Given the previous research questions, the aims of the seminar are as follows:

1. To **bring together** academics and practitioners from data visualization, data science, design, pedagogy and education.
2. **Share experience and discuss** current practices and knowledge, activities, materials, contexts, core structures, tools and platforms in teaching visualization literacy.
3. **Reflect on challenges** in porting existing methods from teaching visualization literacy and pedagogy to novel teaching contexts such as online learning and individual learning.
4. **Collect visualization teaching activities.** We will pre-publish a template for seminar invitees to submit their activities. Activities will then be discussed at the seminar alongside discussions to refine the initial template. After the seminar, participants will be encouraged to submit further visualization activities. We aim to publish all gathered activities in our visualization activities cookbook. We envision this book as a recipe book that describes process, components, and the outcomes of different activities for teaching, designing, and communicating visualization. We see in this gathering a unique opportunity to formalize this practice and share it with the community.
5. **Create and test novel visualization activities** and materials through a facilitated session at the seminar (see Seminar Outline). In break-out groups, this session will ask participants to design an activity to meet a specific challenge (e.g., teaching visual variables to school-aged children). Activities will be tested and discussed by other groups. After the seminar, participants will have time to implement, test, and refine their activity for the final cookbook.
6. **Outline a research agenda** to address the questions mentioned in Section *Research Questions* and complement this agenda with additional questions from discussions and practical seminar activities.
7. **Facilitate the creation of concrete research** projects and collaborations among the seminar participants to implement this research agenda.
8. **Outline resources and strategies** of how we can continue sharing and discussing knowledge around visualization literacy education, e.g., workshops, conferences, seminars, talks series, central repositories and web platforms, education standards, etc.

4 Impact

This seminar aims to give practical impulses and pointers for research, application, education and policy making.

- **Research:** our seminar aims to inform research in, e.g.,
 - creating more accessible and usable data visualization techniques and tools;
 - activities and material to support specific skills, contexts, and audiences;
 - metrics to assess visualization literacy and learning methods;
 - understand audiences' needs to use visualizations;
 - Common misperceptions and fallacies;
 - etc.
- **Education:** we expect the importance of visualization literacy in education to grow and aim to provide starting points for classical course creation and design as well as for less traditional approaches in online teaching, large classes, and professional development but also for self-directed learning. We imagine our books to influence a wide range of teachers in academic disciplines such as visualization, data science, public health, design, etc. as well as industry and a diverse range of schools (pre-schools, mid-schools, high-schools, etc).
- **Application:** our seminar aims to inform practitioners in taking visualization literacy into account when designing visualizations and carefully considering ways to teach their audiences.
- **Policy making:** Eventually, we aim to inform policies on education and to provide the basis for more visualization literacy in university and school curricula.

5 Relation to other related seminars

Dagstuhl Seminars

This proposal is the first Dagstuhl seminar on the topic of visualization literacy and education. The specific topic had been discussed informally (including the authors of this proposal) at previous Dagstuhl seminars (Data Physicalization, Data-Driven Storytelling, see below). Previous Dagstuhl seminars have been focusing to some great extent on data visualization in specific domains (e.g., geography, networks) or specific approaches to visualization (e.g., storytelling, physicalization). The topic of visualization literacy and education has been discussed officially in a previous Dagstuhl seminar (Dagstuhl seminar 07721 "*Information Visualization - Human-Centered Issues in Visual Representation, Interaction, and Evaluation*"), leading to a book chapter *Teaching Information Visualization*: Andreas Kerren, Jason Dykes, John Stasko [16].

- Dagstuhl Seminar 07221
Information Visualization—Human-Centered Issues in Visual Representation, Interaction, and Evaluation
 May 28 – June 1, 2007
<http://www.dagstuhl.de/07221>
- Dagstuhl Seminar 12081
Information Visualization, Visual Data Mining and Machine Learning
 19. – 24. Februar 2012
<http://www.dagstuhl.de/12081>
- Dagstuhl Seminar 13352
Interaction with Information for Visual Reasoning
 August 25th – August 30th 2013
<https://www.dagstuhl.de/13352>
- Dagstuhl Seminar 16061
Data-Driven Storytelling
 February 7 – 12, 2016
<https://www.dagstuhl.de/16061>
- Dagstuhl Seminar 18441
Data Physicalization

October 28 – November 2, 2018
<https://www.dagstuhl.de/18441>

Conference Workshops

The authors of this proposal are organizing two conference workshops on related topics this year at the IEEE VIS conference in October 2020.

- **Data visualization activities to facilitate learning, reflecting, discussing, and designing:** Samuel Huron, Benjamin Bach, Uta Hinrichs, Jonathan Roberts, Mandy Keck. <http://visactivities.github.io>
- **3rd Workshop on the Creation, Curation, Critique and Conditioning of Principles and Guidelines in Visualization.** Alfie Abdul-Rahman, Alexandra Diehl, Benjamin Bach <https://nms.kcl.ac.uk/c4pgv>

Other previous workshops and panels highlight the increased awareness of the topic in the scientific community:

- IEEE VIS 2018: **VisGuides: 2nd Workshop on the Creation, Curation, Critique and Conditioning of Principles and Guidelines in Visualization:** Alexandra Diehl, Benjamin Bach, Alfie Abdul-Rahman
- ACM DIS 2017: **Pedagogy & Physicalization: Designing Learning Activities around Physical Data Representations.** Trevor Hogan, Uta Hinrichs, Yvonne Jansen, Samuel Huron, Pauline Gourlet, Eva Hornecker and Bettina Nissen. <http://dataphys.org/workshops/dis17/>
- IEEE VIS 2017: **Pedagogy of Visualization (PDVW; 2nd workshop).** Alark Joshi, Eytan Adar, Sophie Angle, Enrico Bertini, Marty Hearst, Daniel Keefe. <http://vgl.cs.usfca.edu/pdvw/2017/>
- IEEE VIS 2016: **Pedagogy of Visualization (PDVW; 1st workshop):** Alark Joshi, Eytan Adar, Sophie Angle, Marty Hearst, Daniel Keefe. <http://vgl.cs.usfca.edu/pdvw/2016/>
- IEEE VIS 2015 Panel: **Vis, the next generation: Teaching across the researcher-practitioner gap:** M. Hearst, E. Adar, R. Kosara, T. Munzner, J. Schwabish, and B. Shneiderman. (IEEE VIS'15 panel). <http://www.cond.org/teachvis.html>

6 Structure of the Seminar

Before the Seminar, we will ask participants to submit information (e.g., activities, procedures, materials, etc.) of visualization activities they know, have tried and/or have come up with themselves, using a provided template. Participants are invited to browse through submitted activities in preparation to the seminar.

The seminar itself is divided into two parts.

Part 1: Research and challenges in visualization education & teaching. This first part will feature introductory talks and 1–2 longer 'keynote' talks on education and visualization literacy. These talks will lead into discussions of open problems and challenges around visualization literacy, education, and visualization literacy. Our research questions outlined above will provide a starting point for discussion breakout groups. We then aim to break into smaller working groups for Monday, Tuesday and Wednesday morning to discuss open challenges, compile existing material, and exchange experiences to structure the handbook.

Part 2: Applicable visualization activities for teaching & education. This second part of the seminar will start with brief group discussion on defining scenarios and challenges for teaching activities on Thursday morning. Then, we create again smaller breakout groups to design and discuss activities to address the given scenarios. Eventually, if time permits, we aim to test and experience activities and to receive mutual feedback on activities.

Friday morning will be reserved for a general reflection on the seminar and to discuss steps to plan beyond the seminar, e.g., planning to editing both books (edited by the seminar organizers), organize working groups and ways of working beyond the seminar, discuss a general *visualization activity* template as well as further community activities in future (e.g., workshops, journals, etc.).

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